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ABSTRACT

This study was undertaken to better understand the ways teachers utilize a reform elementary mathematics curriculum in the beginning stages of implementation and the factors that influence the implementation. The teacher's beliefs about mathematics teaching, his understanding of students' reasoning, and the ways he engaged with his students' reasoning were analyzed in order to obtain a clearer picture of what teachers bring to the implementation of a new curriculum. While the teacher believed in reform and the curriculum he was using, he struggled to transform his teaching to focus on understanding. He was particularly challenged by eliciting and pursuing a variety of strategies rather than the ones he had in mind and using incorrect responses as a site for learning. (Author)

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WHAT IMPACTS TEACHERS AS THEY IMPLEMENT A REFORM CURRICULUM?: THE CASE OF ONE FIFTH GRADE TEACHER

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Abstract: This study was undertaken to better understand the ways teachers utilize a reform elementary mathematics curriculum in the beginning stages of implementation and the factors that influence the implementation. The teacher's beliefs about mathematics teaching, his understanding of students' reasoning, and the ways he engaged with his students' reasoning were analyzed in order to obtain a clearer picture of what teachers bring to the implementation of a new curriculum. While the teacher believed in reform and the curriculum he was using, he struggled to transform his teaching to focus on understanding. He was particularly challenged by eliciting and pursuing a variety of strategies rather than the ones he had in mind and using incorrect responses as a site for learning.

Theoretical Perspective

For the past decade, the Standards documents put forth by the National Council of Teachers of Mathematics (1989, 1991, 1995, 2000) have forced us to rethink *what* mathematics is taught, *how* that mathematics is taught, and the intricate interplay between content and pedagogy. Initial reactions to these documents were often simplistic, focusing on a single aspect of the vision such as simply adding certain content or using cooperative groups (Burrill, 1997). The development and publication of Standards-based curricula that make this vision more explicit provide a unique opportunity to avoid these superficial interpretations of the Standards. However, the challenge still exists as to how to support teachers as they implement reform curricula.

Although the research on teacher change has provided us with a better understanding of the complex process of changing beliefs and practice (e.g., Lloyd, 1999; Simon & Schifter, 1991; Wood, Cobb, & Yackel, 1991), we are just beginning to understand how to best facilitate change in the climate of reform (Ball, 1996). Recently researchers have suggested that there are essential characteristics of classrooms that support the growth of mathematical understanding, including the ability of teachers to elicit children's solution methods and enable them to extend their mathematical thinking (e.g., Fraivillig, Murphy, & Fuson,1999; Empson, 2000). Our research, studying a sample of elementary teachers from the more than 400 in our project as they implement a reform mathematics curriculum, has also led us to conclude that it is the teachers' ability to focus on students' reasoning and distinguish among those that are math-

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ematically significant that impacts their ability to implement the curriculum (Grant & Kline, 2002). We undertook this intensive study of a teacher's day-to-day practice to more deeply analyze the factors that influence the in-the-moment decisions made while teaching a reform curriculum and develop further this theoretical stance about teachers' abilities to engage with students' ideas.

Setting the Stage

For the past three years the authors have been working with several local elementary school districts as they work to improve the mathematics instruction in their schools. These districts have all adopted one of the NSF-funded reform curricula, *Investigations in Number, Data and Space* (henceforth called *Investigations*). This study takes place in a fifth-grade mathematics class at the beginning of the final year of a three-year phased implementation of *Investigations* in a small rural school district. The teacher of this class, Doug, has been a teacher for almost 20 years and has just returned to teaching after being a middle school administrator for ten years. Doug taught two sections of mathematics to the fifth grade students in his building and one of those sections was used for the study. Doug volunteered to participate in the study and was anxious to receive feedback on his teaching.

As fifth grade was the last grade to implement the new curriculum, this was the first year Doug taught mathematics using these materials. The majority of his students had their first exposure to the *Investigations* curriculum in fourth grade. However that year was the first year for the fourth grade teachers to implement the curriculum and there was some indication that two of the three teachers in this particular school did not use the curriculum whole-heartedly. Prior to fourth grade Doug's students had received instruction from a traditional textbook.

Data Collection and Analysis

An ethnographic approach was used to observe and interact with the students and teacher in this study. The teacher was observed daily by the authors while the first unit of the reform curriculum was taught, lasting approximately eight weeks. The unit focused on whole number computation and number sense, developing such ideas as factors and multiples, using known multiplication and division problems to figure out unknown ones, and the relationship between multiplication and division.

A classroom observation instrument adapted from the QUASAR project (Stein, Grover & Silver, 1991) was used to capture such aspects of the implemented lesson as the general format (e.g., launch, students at work, and closure; use of whole-group, small-group or individuals at work); the ways students were and were not supported in their investigations and reasoning about mathematics (particular attention was paid to the ways the teacher probed student thinking); and the ways in which the lessons were altered. Brief interviews were conducted with the teacher before and after most lessons to ascertain what he was thinking going into the lesson and his reflections

following the lesson. In addition, an extensive final interview was conducted at the end of the unit to investigate the teacher's reflections on the entire unit and what was learned about mathematics, teaching, and how students were thinking. The questions included: Have you learned anything new about number from teaching this unit?; What was the mathematical emphasis of this unit?; Overall, did your students develop an understanding of this mathematical emphasis?; Did any of the students' thinking surprise you during the unit?; What does the student work from the final assessment in the unit tell you about what they understand?; How do you feel your teaching has changed?; and What is the most challenging aspect of teaching Investigations? This interview was audio-taped and transcribed.

Field notes from observations and pre- and post-observation interviews were compiled and discussed by the researchers throughout the eight weeks. This allowed for the use of a "grounded theory" (Glaser & Strauss, 1967) approach to data collection and analysis, which was particularly instrumental in guiding conversations with the teacher and focusing his attention on particular aspects of his teaching that were at odds with the curriculum. The field notes were analyzed after completion of the study as well to identify patterns in the way Doug was interacting with his students.

Results and Discussion

In our preliminary interview with Doug, he indicated that his philosophy about teaching aligned with that of *Investigations*. Doug explained that he liked being flexible and allowing a lesson to go where the students took it. He believed it was important that students understand mathematics and not just memorize procedures taught to them. Doug had typical reservations about being new to the curriculum, but looked forward to using it. However as he taught this first unit, he clearly struggled to keep the focus on students' understanding. Our analysis of the data yielded several key issues that challenged Doug in his teaching; these are described in the following sections. Although many of the issues Doug faced are related, they will be discussed separately below to highlight their unique contributions to understanding the challenges of changing ones practice.

Terminology before Concepts

On our first observation, Doug decided not to use the curriculum, but rather gave the students a worksheet to work on in pairs and then a similar one to do independently as an assessment. The worksheet involved identifying factors and multiples of specific numbers, identifying prime numbers, and odd and even numbers. The mode of instruction was direct instruction with the teacher as the clear authority in the classroom. No questions were asked about how students arrived at solutions or about how they were thinking. Doug explained that he felt it was necessary to do this activity to give the students a chance to get a handle on the terminology they would be using in the unit. He believed that they needed to know this terminology before they could

do any investigations about numbers and their characteristics. This belief that definitions and terminology should be learned *before* investigating ideas, rather than *while* investigating ideas, reappeared in Doug's teaching throughout the unit. This view that terminology must be learned first is in conflict with the curriculum's approach to learning and can undermine the students' ability to thoroughly understand the concept(s) represented by the terminology.

Focusing on Predetermined Strategies

While Doug expressed a belief in the importance of developing a variety of strategies, he tended to focus on one or two strategies that he thought were the most important, many times in neglect of other strategies. For example, students were asked to think about how they could figure out the answer to 6 x 8 if they did not have it memorized already. One student suggested starting with 5 x 8 = 40 and then adding on one more 8 to get 48. Doug accepted this along with one more strategy and then said, "Can't we use 3 x 8 = 24 and then double?" He suggested this doubling strategy with a tone that almost negated the others that were shared previously. In other instances, like the one described below, Doug chose to alter the lesson by either eliminating open-ended questions designed to probe thinking or replacing them with more focused questions designed to focus on particular strategies. This pattern reoccurred throughout the unit, often making it clear that he valued certain strategies over others.

It is certainly the case that some strategies should be highlighted for their efficiency and mathematical importance. However, Doug often singled out strategies early in a lesson which tended to circumvent the students' thinking and use of other equally important strategies. For example, in one lesson where students were asked to find as many factors as possible for 100, 1000, and 10,000, Doug focused on only two strategies. He explained to the students that they could skip count by a number and if they landed on 1000, it was a factor of 1000. An alternative strategy he suggested they use was to divide the number they were thinking of into 1000 on the calculator and use it if the answer was a whole number. The lesson plan does suggest that you begin with the idea of skip counting, since the students have been working on skip-counting patterns for various numbers. However, the lesson plan also reads, "Record only one or two suggestions for each number and ask: How can you use what you already know to find some more numbers without actually doing the counting all the way to 1000 or 10,000?" (Kliman, Tierney, Russell, Murray, & Akers, 1998, p. 51). Students could potentially bring a variety of perspectives to this investigation. They had been working with area models for multiplication and could think of rectangle dimensions. They could also use factors from one list (factors of 100) to help them think about factors of 1000 or 10,000. Because of the suggestions Doug made at the beginning of the lesson and continued to reinforce while students were working, the notion of searching for relationships among factors (a key mathematical emphasis of this lesson) was lost.

Authority on Correctness

Doug was the clear authority on the correctness of solutions in the classroom. He rarely pursued incorrect solutions to ascertain whether the reasoning was valid, but rather would inform students that they were incorrect and proceed to another student. A routine that was revisited throughout the unit was to skip count by a given number. On one day, students were working on skip counting by 400. On two different occasions, students provided an incorrect response. Rather than using that as an opportunity to let those students and the entire class think about the situation, Doug would simply tell the student he was wrong and tell him how to think about it. For example, one student was to add 400 to 1200 and said 1500. Doug told him he was wrong and said, "What is 2 + 4? Okay, so what is 1200 + 400?" On another occasion, students were working on factor pairs for 300. One student offered 50 x 5 and Doug would not write it on the board. Rather, he said, "50 is right," and wrote 50 x ___ on the board. The student then offered 5 x 60 and Doug replied, "You're almost there, but we're working with 50." Clearly, these exchanges established his authority in the classroom and undermined some of the thinking that the students could have done around these issues.

Selective Pursuit of Reasoning

When explanations of thinking are part of teaching, it is not uncommon for students to offer incomplete, unclear, and sometimes nonsensical responses. A large part of the challenge of orchestrating discussions around student thinking is to pursue these kinds of responses to figure out what makes sense. Doug would occasionally find himself confronted with such explanations and be unsure of how to proceed. For example, during a lesson early in the unit a student offered the following strategy to figure out 6 x 8: he said he would begin with 6 x 10 = 60, and then take off 4, and take off 4, and take off 4 to get 48. The student explained that he would take off 4's because they are easy to subtract. It was clear that the student knew the answer to 6 x 8 was 48, and was starting with 60 and subtracting 4's until he got to the correct answer. While Doug recognized there was something odd about this strategy, he decided to not pursue it and go on to another student.

It would have been beneficial to discuss this nonsensical approach for a variety of reasons, however. In the first place, the students need to understand that simply arriving at "the answer" does not legitimize any approach. The approach must always make sense in the context of the problem/situation. The second issue is that the use of a nonsensical approach can virtually bypass the mathematics of the context. One could begin the problem at hand by interpreting 6 x 8 as 6 groups of 8 (8 groups of 6) and using other known groups (i.e. 6 x 10 or 6 groups of 10) to help them figure out the solution. And it is the compensation done at this point (taking away 6 groups of 2, 6 x 10 - 6 x 2 = 6 x 8) that must utilize an understanding of these groupings in order to sensibly arrive at a solution.

By not addressing the issue of nonsensical approaches to problems nor the mathematics underlying invented approaches to multiplication, future lessons posed greater challenges. For example, as students began working on invented procedures for multiplying larger numbers, they struggled to develop appropriate ways to break down the problems into simpler problems they could use.

Attempting Changes

During the unit, Doug made several attempts to change his practice to focus more on student thinking. About half-way through the unit, he made a conscious effort to position himself differently in the classroom. He would often stand in the back of the room and let students go to the front as they shared their reasoning. He also attempted to pursue incorrect responses on occasion. In one lesson, students were provided with a set of related problems (4 x 25, 40 x 25, 6 x 25, 10 x 25, 50 x 25) with the goal being to solve 46 x 25 using the solutions to these problems. One student offered his solution at the overhead by saying he created his own related problems to use. He wrote 40 x 15 and 6 x 15 and explained that you just add the answers to those problems to get the solution to 46 x 25 because 40 + 6 = 46 and 15 + 15 = 25. When the students shouted that 15 + 15 = 30, he changed 6 x 15 to 6 x 10 and was convinced that the answer to 40 x 15 plus the answer to 6 x 10 would be the same as the solution to 46 x 25. Doug knew this was incorrect and chose a particular student to come up and explain why that strategy would not work. Unfortunately, the student did not actually address the incorrect strategy; rather, he decided to share his own correct strategy instead. When asked in the final interview how he felt about pursuing incorrect strategies with the rest of the class, Doug said, "I think it's real important. That's one of the ones I struggle with...how to help other kids see why that's wrong."

Conclusions

The factors that influenced this teacher's implementation of a mathematics reform curriculum have reaffirmed the research finding that one of the most important factors of successful implementation is the teacher's ability to engage with students' ideas. This case study along with related studies conducted by the authors extends the research by suggesting finer categories/characteristics influencing teachers' ability to make student thinking central. It is essential that teachers believe in the importance of developing a variety of ways of reasoning in mathematics. In addition, they need to have an understanding of the mathematical significance of different ways of reasoning and be able to distinguish among them while teaching. It is also important to realize that the authority for correctness should lie with the classroom as a community, rather than solely with the teacher.

Our work with the larger population of teachers in our project has led us to conjecture that what may be at the heart of these issues is understanding what it means to develop students who are powerful and independent problem solvers. One may

view the major purpose of the *Investigations* curriculum as developing the ability in students to think on their own and to make judgments about the reasonableness of their thinking. If one thinks of the issues involved in teaching reform curricula through this lens, then the way you view the characteristics (described in the previous paragraph) change dramatically. If you view the teacher's role as moving students along a continuum toward being independent problem solvers, the teacher must encourage and elicit multiple strategies and create a classroom environment where explanations on the reasonableness of solutions is the norm. This suggests a framework for thinking about supporting teachers as they implement new curricula and for designing further research on what factors impact teachers' enactment of reform curricula.

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